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(54) **Method for driving a multi-layered-type liquid crystal display device**

Ansteuerungsverfahren einer mehrschichtigen Flüssigkristall-Anzeigevorrichtung

Procédé de commande d'un dispositif d'affichage à cristal liquide multicouche

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Description

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a method for driving a liquid crystal display device, and more particularly, to a method for driving a multi-layered-type liquid crystal display device comprising stacked plural liquid crystal cells for passing light of different colors therethrough.

DESCRIPTION OF RELATED ART

Liquid crystal display devices are now being used widely in various electronic apparatuses such as clocks and electronic calculating machines, displays of computer terminals and word processors, television sets. Recently, there have been extremely high demands for constituting multicolor and full color displays using liquid crystal display devices, and they have already been put in practical use in the fields of graphic display and image display. The color display of this type is attained by arranging color filter layers inside of a liquid crystal cell as a light switcher in order to generate various colors. The major display mode of the liquid crystal display device is called a twisted nematic display mode (referred to as a TN display mode hereinafter), wherein liquid crystal molecules are twisted by an angle of 90° in the liquid crystal cell.

However, in the TN display mode, the dependency of the display characteristic on the wavelength of light is relatively large, and it is difficult to switch the light uniformly over the whole range of the visible light. Particularly, in a normally closed type liquid crystal display device in which the polarization axes of two polarizers are parallel to each other, coloring of the display may be caused due to leakage of the light when no voltage is applied to the liquid crystal layer, and therefore, it is difficult to adopt the TN display mode in a full color display.

In a color liquid crystal display device utilizing the TN display mode, wherein the aforementioned color filter layer is arranged, there have been mainly proposed the following two driving methods as methods for driving the color liquid crystal display device. One is an active matrix driving method, and another is a simple multiplex driving method.

In a liquid crystal display device utilizing the active matrix driving method, non-linear devices such as diodes or switching devices such as thin film transistors are provided at respective pixels of the liquid crystal cell, and the liquid crystal layer of each pixel is driven selectively.

In a liquid crystal display device utilizing the simple multiplex driving method, there are not provided non-linear devices or switching devices, and the liquid crystal layer of each pixel is driven sequentially. In this liquid crystal display device, a steepness near the threshold value presents a problem among optical characteristics of the liquid crystal, in which the TN display mode is used.

In order to improve the optical characteristics exhibiting the steepness near the threshold value, there has been proposed a Super Twisted Nematic method (referred to as an STN method hereinafter) as a method for orienting liquid crystal molecules, wherein the twisted angle is set so as to have a value between 180° and 270°. In the STN method, the curve rises steeply in the vicinity of the threshold value, and it is possible to obtain a high contrast ratio even under a high duty ratio. However, because it utilizes the birefringence effect of the liquid crystal, the dependence of the display characteristics on the wavelength of light is higher than that of the TN display mode, and thereby, coloring of the display becomes much more severe.

Furthermore, in order to display a multicolor image, generally, a color filter layer is provided as described above. In this case, however, there are such problems that the manufacturing process therefor is complicated and the manufacturing cost increases.

EP-A-0 246 842 discloses a liquid crystal display comprising two stacked cell layers. One of the cell layers is provided with electrodes for applying a voltage in accordance with an image to be displayed. The other cell layer is not controlled by a voltage; its purpose is to neutralise colors occurring from the birefringence of the liquid crystals in the layers. A multi-color image is achieved by providing color filters. A similar display device is described in WO 89/03542, which belongs to the state of the art under Article 54(3) EPC, with reference to Figure 4 thereof. Here, a second cell layer, for neutralising colors, is additionally provided with electrodes for the application of a voltage.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a liquid crystal display device and a method for driving the same which allows control of the color of a displayed image in a simplified way.

This object is met by the method defined by independent claim 1 and the display device defined by independent claim 13. The dependent claims are directed to preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view showing a fundamental structure of a double-layered-type liquid crystal display device of preferred embodiments according to the present invention;

Figs. 2a and 2b are diagrams schematically showing twists of liquid crystal molecules in left and right directions, respectively;

Fig. 3 is a graph of characteristic curves showing the relation between a twist angle θ_1 of a liquid crystal layer of a double-layered-type liquid crystal and a contrast ratio of a displayed monochromatic image;

Fig. 4a is a graph of R, G and B characteristic curves showing a relation between a voltage applied to a liquid crystal cell layer 1 and a light transmittance when a voltage is applied to a liquid crystal cell layer 2 in the double-layered type liquid crystal display device of a first preferred embodiment;

Fig. 4b is a graph of R, G and B characteristic curves showing a relation between a voltage applied to the liquid crystal cell layer 1 and a light transmittance when no voltage is applied to the liquid crystal cell layer 2 in the double-layered-type liquid crystal display device of the first preferred embodiment;

Fig. 5a is a graph of R, G and B characteristic curves showing the relation between a voltage applied to a liquid crystal cell layer 1 and a light transmittance when a voltage is applied to a liquid crystal cell layer 2 in a double-layered-type liquid crystal display device of a second preferred embodiment;

Fig. 5b is a graph of R, G and B characteristic curves showing the relation between a voltage applied to the liquid crystal cell layer 1 and a light transmittance when no voltage is applied to the liquid crystal cell layer 2 in the double-layered-type liquid crystal display device of the second preferred embodiment;

Fig. 6a is a graph of R, G and B characteristic curves showing the relation between a voltage applied to a liquid crystal cell layer 1 and a light transmittance when no voltage is applied to a liquid crystal cell layer 2 in a double-layered-type liquid crystal display device of a third preferred embodiment; and

Fig. 6b is a graph of R, G and B characteristic curves showing the relation between a voltage applied to the liquid crystal cell layer 1 and a light transmittance when a voltage is applied to the liquid crystal cell layer 2 in the double-layered-type liquid crystal display device of the third preferred embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments according to the present invention will be described below with reference to the attached drawings.

First preferred embodiment

Fig. 1 is a cross sectional view showing a fundamental structure of a double-layered-type liquid crystal device to which there is applied a driving method of a first preferred embodiment according to the present invention.

Referring to Fig. 1, the liquid crystal display device has a double layered structure composed of first and second cell layers 1 and 2 containing liquid crystal layers 6a and 6b, respectively. In the liquid crystal layers 6a and 6b, liquid crystal molecules are arranged in a twisted nematic phase.

The first and second cell layers 1 and 2 are formed so as to be stacked on respective surfaces of a common transparent substrate 3b. The first cell layer 1 has such a structure that the liquid crystal layer 6a is contained between two transparent substrates 3a and 3b and is sealed by a sealing element 7a, and orientation membranes 5aa and 5ab for orienting liquid crystal molecules in a twisted nematic phase are formed on respective inner surfaces of the transparent substrates 3a and 3b. The first cell layer 1 has transparent electrically conductive electrode films 4a and 4b for applying a voltage to the liquid crystal layer 6a, which are formed on respective inner surfaces of the transparent substrates 3a and 3b. Further, there is formed a polarizer 8a on the outer surface of the outer substrate 3a.

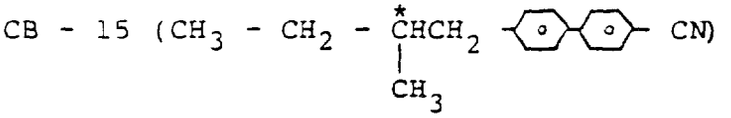
The second cell layer 2 has such a structure that the liquid crystal layer 6b is contained between two transparent

substrates 3b and 3c and is sealed by a sealing element 7b, and orientation membranes 5ba and 5bb for orienting liquid crystal molecules in a twisted nematic phase are formed on respective inner surfaces of the transparent substrates 3b and 3c.

The second cell layer 2 has transparent electrically conductive electrode films 4c and 4d for applying a voltage to the liquid crystal layer 6b, which are formed on respective inner surfaces of the transparent substrates 3b and 3c. Further, there is formed a polarizer 8b on the outer surface of the outer substrate 3c so that the polarization axes of the polarizers 8a and 8b cross each other at an angle in the range from zero to 30°.

Each of the transparent substrates 3a to 3c may be made of glass, acrylic resin, or the like, and each of the transparent electrode films 4a to 4d may be made of ITO which is a film mainly made of indium oxide, a NESA film, or the like. Each of the orientation membranes 5aa, 5ab, 5ba and 5bb may be made of an inorganic material such as SiO_2, SiO, or the like or an organic material such as polyimide, polyvinyl alcohol, nylon, acrylic resin, or the like.

In the liquid crystal device shown in Fig. 1, the axes of respective liquid crystal molecules in each of the liquid crystal layers 6a and 6b are twisted helically from the side of one substrate to the side of another substrate of each cell layer, as shown schematically in Figs. 2a and 2b. As is well known to those skilled in the art, the direction of twist is defined as either a direction to the right (Fig. 2a) or a direction to the left (Fig. 2b). In order to give a twisting power to individual liquid crystal molecules, generally, at least one optically active material is added into the nematic liquid crystal. In the case of the right twist, for example, the material represented by the following general formula and offered by Merck & Co., Inc. is added thereinto.



On the other hand, in the case of the left twist, cholesteryl nonanoate S-811® offered by Merck & Co., Inc. is added thereinto.

In the double-layered-type liquid crystal display device, in order to enhance the contrast ratio in the case of a monochromatic display and the quality of the display in the case of a multicolor display, or the like, values θ_1 and θ_2 of twist angles of the liquid crystal layers 6a and 6b in the first and second cell layers 1 and 2, and the value $\Delta n_1 \cdot d_1$ of a product of the birefringence Δn_1 of the liquid crystal layer 6a and the thickness d_1 thereof and the value $\Delta n_2 \cdot d_2$ of a product of the birefringence Δn_2 of the liquid crystal layer 6b and the thickness d_2 thereof are adjusted so as to satisfy the following requirement.

(a) The values $\Delta n_1 \cdot d_1$ and $\Delta n_2 \cdot d_2$ are adjusted so as to satisfy the following inequalities (1) and (2) in order to obtain the aforementioned excellent display characteristics, which is confirmed by the experiment performed by the inventors of the present invention.

$$1.0 < | \Delta n_1 \cdot d_1 | < 3.5 \quad (1)$$

$$1.0 < | \Delta n_2 \cdot d_2 | < 3.5 \quad (2)$$

(b) In order to maximize the contrast ratio in the case of the monochromatic display, the values $\Delta n_1 \cdot d_1$ and $\Delta n_2 \cdot d_2$ are adjusted so as to satisfy the following inequality (3), which is confirmed by the experiment performed by the inventors of the present invention.

$$0.8 < \Delta n_2 \cdot d_2 / \Delta n_1 \cdot d_1 < 1.5 \quad (3)$$

(c) In order to display a monochromatic image by selectively applying an ON voltage for enabling light to pass through the liquid crystal layer 6a of the first cell layer 1 or an OFF voltage for disabling light to pass through the liquid crystal layer 6a under the condition that a predetermined voltage is applied to the liquid crystal layer 6b of the second cell layer 2, and also to display a two-color image based on interference colors by selectively applying the aforementioned ON or OFF voltage to the liquid crystal layer 6a of the first cell layer 1 under the condition that no voltage is applied to the liquid crystal layer 6b of the second cell layer 2, the values $\Delta n_1 \cdot d_1 \cdot \theta_1$ and $\Delta n_2 \cdot d_2 \cdot \theta_2$ are adjusted so as to satisfy the following inequality (4), which is confirmed by the experiment performed by the inventors of the present invention.

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 > 0.9 \quad (4)$$

In order to display a monochromatic image by selectively applying the aforementioned ON or OFF voltage to the liquid crystal layer 6a of the first cell layer 1 under the condition that no voltage is applied to the liquid crystal layer 6b of the second cell layer 2, and also to display a two-color image based on interference colors by selectively applying the aforementioned ON or OFF voltage to the liquid crystal layer 6a of the first cell layer 1 under the condition that a predetermined voltage is applied to the liquid crystal layer 6b of the second cell layer 2, the values $\Delta n_1 \cdot d_1 \cdot \theta_1$ and $\Delta n_2 \cdot d_2 \cdot \theta_2$ are adjusted so as to satisfy the following inequality (5), which is confirmed by the experiment performed by the inventors of the present invention.

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 < 1.1 \quad (5)$$

(d) Fig. 3 shows the relation between a twist angle θ_1 of the liquid crystal layer 6a and a contrast ratio of a displayed monochromatic image in the double-layered-type liquid crystal device. As shown in Fig. 3, each contrast ratio of displayed monochromatic images in the case of $\theta_2 = \theta_1 - 30°$ is larger than that in the case of $\theta_1 = \theta_2$. Therefore, when the display contrast and the visibility are taken into consideration, the twist angle θ_1 of the liquid crystal layer 6a of the first cell layer 1 is preferably set so as to fall in the range from about 180° to about 360°. If the twist angle θ_1 exceeds 360°, domains appear in the liquid crystal layer 6a in which each liquid crystal has an orientation disarrayed at the time of the application of a predetermined voltage, resulting in a dispersion of light, which readily causes a decrease in the contrast.

Furthermore, when the display contrast is taken into consideration, the twist angle θ_2 of the liquid crystal layer 6b of the second cell layer 2 is preferably set so as to fall in the range from about 30° to about 360° and to be different from the twist angle θ_1 of the liquid crystal layer 6a of the first cell layer 1.

In order to obtain a steep threshold characteristic in the contrast, the specific pitch p of the helical twist of liquid crystal is considered to be very important. The ratio d/p of the thickness d of each of the liquid crystal layers 6a and 6b to the pitch p of the helical twist of the liquid crystal therein is preferably set so as to satisfy the following relation, which is confirmed by the experiment performed by the inventors of the present invention.

$$\theta / 360° - 1/4 < d/p \leq \theta / 360° \quad (6),$$

wherein θ is the twist angle of the liquid crystal. This requirement can be applied only to the case that the pretilt angle of the liquid crystal is equal to or smaller than about 10°. In the case that the pretilt angle thereof exceeds 10°, the range to be satisfied by the ratio d/p becomes different from the range represented by the inequality (6).

Figs. 4a and 4b are graphs of characteristic curves showing the relation between a voltage applied to the liquid crystal layer 6a of the first cell layer 1 and a light transmittance in the double-layered-type liquid crystal device shown in Fig. 1, wherein Fig. 4a shows the characteristics in the case of a monochromatic display, and Fig. 4b shows the characteristics in the case of a multicolor display.

First of all, a method for driving the double-layered-type liquid crystal device so as to display a monochromatic image and the action thereof will be described below with reference to Fig. 4a.

Under the condition that a predetermined voltage is applied between the transparent electrode films 4c and 4d of the second cell layer 2 so as to be applied to the liquid crystal layer 6b, an ON voltage of about 1.7 V or an OFF voltage of about 1.5 V is selectively applied between the transparent electrode films 4a and 4b of the first cell layer 1 with use of a simple multiplex driving method so as to be applied to the liquid crystal layer 6a. Then, the orientation direction of the liquid crystal molecules on each pixel of an area of the liquid crystal layer 6a where the transparent electrode films 4a and 4b cross each other changes according to the voltage applied thereto. The light having passed through the first and second cell layers 1 and 2 passes through the polarizer 8b when the OFF voltage is applied to the liquid crystal layer 6a. On the other hand, the light having passed through the first and second layers 1 and 2 is shaded by the polarizer 8b when the ON voltage is applied thereto.

Namely, as shown in Fig. 4a, when red color light R having a wavelength of 610 nm, green color light G having a wavelength of 550 nm and blue color light B having a wavelength of 450 nm are incident substantially perpendicularly to the outer surface of the polarizer 8a from the outer side thereof to the liquid crystal device, they pass through each partial area of the polarizer 8b corresponding to each of a first group of pixels of the liquid crystal layer 6a to which the OFF voltage is applied, and then, a white color image is displayed on each of the first group of pixels. On the other hand, the red color light R, the green color light G and the blue color light B are shaded by each partial area of the polarizer 8b corresponding to each of a second group of pixels of the liquid crystal layer 6a to which the ON voltage is applied, and then, a black color image is displayed on each of the second group of pixels. Therefore, a monochromatic image composed of white and black color images is displayed on the double-layered-type liquid crystal device. In the double-layered-type liquid crystal device, the second cell layer 2 acts as a compensator for compensating a color tone of the light having passed through the first cell layer 1, resulting in an excellent monochromatic display without interference colors.

Next, a method for driving the double-layered-type liquid crystal device so as to display a multicolor image and the action thereof will be described below with reference to Fig. 4b.

Under the condition that no voltage is applied to the liquid crystal layer 6b of the second cell layer 2, the ON or OFF voltage is selectively applied to the liquid crystal layer 6a of the first cell layer 1 in the manner similar to the case of the aforementioned monochromatic display. Then, as shown in Fig. 4b, the red color light R, the green color light G and the blue color light B are shaded by each partial area of the polarizer 8b corresponding to each of a first group of pixels of the liquid crystal layer 6a to which the OFF voltage is applied, and then, a black color image is displayed on each of the first group of pixels. On the other hand, the light transmittance of only the blue color light B on each of a second group of pixels corresponding to the liquid crystal layer 6a to which the ON voltage is applied increases, and then, a blue color image is displayed on each of the second group of pixels. Therefore, a two-color image composed of black and blue color images is displayed on the double-layered-type liquid crystal device. Namely, the characteristic of the function for compensating the color tone of the second cell layer 2 changes by switching over from such a state that the predetermined voltage is applied to the liquid crystal layer 6b to such a state that no voltage is applied thereto, resulting in a change in the color of the displayed image.

If the second cell layer 2 is driven statically so as to switch over from such a state that the predetermined voltage is applied to the substantially whole area of the liquid crystal layer 6b to such a state that no voltage is applied thereto, the whole image surface of the double-layered-type liquid crystal device can be switched over from a monochromatic display for selectively displaying a white color image or a black color image thereon to a two-color display for selectively displaying a black color image or a blue color image thereon. Furthermore, by switching over from such a state that the predetermined voltage is applied to the whole area of the liquid crystal layer 6b of the second cell layer 2 corresponding to all the pixels to such a state that no voltage is applied only to a partial area of the liquid crystal layer 6b corresponding to any selected group of pixels with use of a simple multiplex driving method, a two-color image composed of black and blue color images is displayed on the selected group of pixels in such a state that a monochromatic display composed of white and black color images is displayed on the other groups of pixels, resulting in that a multicolor display on the whole surface of the double-layered-type liquid crystal device.

Second preferred embodiment

Fig. 5a and 5b are graphs of characteristic curves showing the relation between a voltage applied to a liquid crystal layer 6a of a first cell layer 1 and a light transmittance in a double-layered-type liquid crystal device of a second preferred embodiment according to the present invention, wherein Fig. 5a shows the characteristics in the case of a monochromatic display, and Fig. 5b shows the characteristics in the case of a multicolor display. The double-layered-type liquid crystal device of the second preferred embodiment has a structure similar to that of the first preferred embodiment. Therefore, the composition of the double-layered-type liquid crystal device of the second preferred embodiment will be described below with reference to Fig. 1.

In this double-layered-type liquid crystal device, transparent substrates 3a to 3c are made of glass. After films of ITO having a thickness of about 1500 Å are deposited on the inner surface of the transparent substrate 3a, both the surfaces of the transparent substrate 3b and the inner surface of the transparent substrate 3c by the vapor deposition method, they are etched so as to have desirable patterns, resulting in transparent electrical conductive electrode films 4a to 4d formed thereon. On each of the transparent electrode films 4a to 4d, orientation membranes 5aa, 5ab, 5ba and 5bb of polyimide are formed with a thickness of about 500 Å by a spin coating technique, the surfaces of which are treated by rubbing with cloth, causing the liquid crystal molecules to be in a parallel orientation.

A liquid crystal layer 6a of the first cell layer 1 is made of a liquid crystal ZLI-1691 made by Merck & Co., Inc., to which 0.72 wt% of cholesteryl nonanoate is added as an optically active material. A liquid crystal layer 6b of the second cell layer 2 is made of a liquid crystal ZLI-3449-000 made by Merck & Co., Inc., to which 1.0 wt% of CB-15 is added. The twist direction of the liquid crystal layer 6a is opposite to that of the liquid crystal layer 6b, and the twist angles θ_1 and θ_2 of the liquid crystal layers 6a and 6b are set at 240° and 270°, respectively. The thickness d_1 of the first cell layer 1 is about 7 μm, and the thickness d_2 of the second cell layer 2 is about 12 μm. Furthermore, the pitch p of the helical twist of the liquid crystal layer 6a is about 14 μm, and that of the liquid crystal layer 6b is about 20 μm. The pretilt angle of each of the liquid crystal arranged between the orientation membranes 5aa and 5ab and the liquid crystal arranged between the orientation membranes 5ba and 5bb are set at about 8°. The polarizers 8a and 8b are made of a compound including iodine, and are formed on the outer surfaces of the outer transparent substrates 3a and 3c so that the polarization axes thereof cross each other at an angle of 30°.

When respective values are set as described above, the aforementioned inequalities (1) to (4) are satisfied. Particularly, when the inequality (4) is satisfied, the ON or OFF voltage is selectively applied to the liquid crystal layer 6a of the first cell layer 1 under the condition that the predetermined voltage is applied to the liquid crystal layer 6b of the second cell layer 2 so as to display a monochromatic image on the double-layered-type liquid crystal device. On the other hand, the ON or OFF voltage is selectively applied to the liquid crystal layer 6a of the first cell layer 1 under the

condition that no voltage is applied to the liquid crystal layer 6b of the second cell layer 2 so as to display a two-color image thereon based on interference colors.

First of all, a method for driving the double-layered-type liquid crystal device so as to display a monochromatic image and the action thereof will be described below with reference to Fig. 5a.

Under the condition that a predetermined voltage applied to the liquid crystal layer 6b of the second cell layer 2, an ON voltage of about 2.2 V or an OFF voltage of about 2.0 V is selectively applied between the transparent electrode films 4a and 4b of the first cell layer 1. Then, the light having passed through the first and second cell layers 1 and 2 passes through the polarizer 8b when the OFF voltage is applied to the liquid crystal layer 6a. On the other hand, the light having passed therethrough is shaded by the polarizer 8b when the ON voltage is applied thereto.

Namely, as shown in Fig. 5a, the red color light R, the green color light G and the blue color light B pass through each partial area of the polarizer 8b corresponding to each of a first group of pixels of the liquid crystal layer 6a to which the OFF voltage is applied, and then, a white color image is displayed on each of the first group of pixels. On the other hand, the red color light R, the green color light G and the blue color light B are shaded by each partial area of the polarizer 8b corresponding to each of a second group of pixels of the liquid crystal layer 6a to which the ON voltage is applied, and then, a black color image is displayed on each of the second group of pixels. Therefore, a monochromatic image composed of white and black color images is displayed on the double-layered-type liquid crystal device.

In the double-layered-type liquid crystal device, the second cell layer 2 acts as a compensator, resulting in an excellent monochromatic display without interference colors in the manner similar to that of the first preferred embodiment.

Next, a method for driving the double-layered-type liquid crystal device so as to display a multicolor image and the action thereof will be described below with reference to Fig. 5b.

Under the condition that no voltage is applied to the liquid crystal layer 6b of the second cell layer 2, the ON or OFF voltage is selectively applied to the liquid crystal layer 6a of the first cell layer 1 in the manner similar to the case of the aforementioned monochromatic display. Then, as shown in Fig. 5b, the light transmittance of only the blue color light B on each of a first group of pixels of the liquid crystal layer 6a to which the OFF voltage is applied increases. On the other hand, the light transmittance of only the green color light G on each of a second group of pixels of the liquid crystal layer 6a to which the ON voltage is applied increases. Therefore, a two-color image composed of blue and green color images is displayed on the double-layered-type liquid crystal device.

If the second cell layer 2 is driven statically so as to switch over from such a state that the predetermined voltage is applied to the substantially whole area of the liquid crystal layer 6b to such a state that no voltage is applied thereto, the whole image surface of the double-layered-type liquid crystal device can be switched over from a monochromatic display for selectively displaying a white color image or a black color image thereon to a two-color display for selectively displaying a green color image or a blue color image thereon. Furthermore, by switching over from such a state that the predetermined voltage is applied to the whole area of the liquid crystal layer 6b of the second cell layer 2 corresponding to all the pixels to such a state that no voltage is applied only to a partial area of the liquid crystal layer 6b corresponding to any selected group of pixels with use of a simple multiplex driving method, a two-color image composed of blue and green color images is displayed on the selected group of pixels in such a state that a monochromatic image composed of white and black color images is displayed on the other groups of pixels, resulting in a multicolor display on the whole surface of the double-layered-type liquid crystal device.

Third preferred embodiment

Figs. 6a and 6b are graphs of characteristic curves showing the relation between a voltage applied to a liquid crystal layer 6a of a first cell layer 1 and a light transmittance in a double-layered-type liquid crystal device of a third preferred embodiment according to the present invention, wherein Fig. 6a shows the characteristics in the case of a monochromatic display, and Fig. 6b shows the characteristics in the case of a multicolor display. The double-layered-type liquid crystal device of the third preferred embodiment has a structure similar to that of the first preferred embodiment. Therefore, the composition of the double-layered-type liquid crystal device of the third preferred embodiment will be described below with reference to Fig. 1.

In this double-layered-type liquid crystal device, the liquid crystal layers 6a and 6b of the first and second cell layers 1 and 2 are made of a liquid crystal ZLI-1691 made by Merck & Co., Inc., wherein 0.63 wt% of cholesteryl nonanoate is added as an optically active material to the liquid crystal layer 6a, and 0.93 wt% of CB-15 is added as the optically active material to the liquid crystal layer 6b. The twist direction of the liquid crystal layer 6a is opposite to that of the liquid crystal layer 6b, and each of the twist angles θ_1 and θ_2 of the liquid crystal layers 6a and 6b is set at 240°. The thickness d_1 of the first cell layer 1 is about 8 μm, and the thickness d_2 of the second cell layer 2 is about 7.5 μm. Furthermore, the pitch p of the helical twist of the liquid crystal layer 6a is about 16 μm, and that of the liquid crystal layer 6b is about 15 μm. The polarizers 8a and 8b are formed on the outer surfaces of the outer transparent substrates 3a and 3c so that the polarization axes thereof cross each other at an angle of zero, namely, the polarization axes thereof become parallel. The other values are set at the same values as that of the second preferred embodiment.

When respective values are set as described above, the aforementioned inequalities (1) to (3) and (5) are satisfied. Particularly, when the inequality (5) is satisfied, the ON or OFF voltage is selectively applied to the liquid crystal layer 6a of the first cell layer 1 under the condition that no voltage is applied to the liquid crystal layer 6b of the second cell layer 2 so as to display a monochromatic image on the double-layered-type liquid crystal device. On the other hand, the ON or OFF voltage is selectively applied to the liquid crystal layer 6a of the first cell layer 1 under the condition that a predetermined voltage is applied to the liquid crystal layer 6b of the second cell layer 2 so as to display a multicolor image thereon based on interference colors.

First of all, a method for driving the double-layered-type liquid crystal device so as to display a monochromatic image and the action thereof will be described below with reference to Fig. 6a.

Under the condition that no voltage is applied to the liquid crystal layer 6b of the second cell layer 2, an ON voltage of about 2,2 V or an OFF voltage of about 2.0 V is selectively applied between the transparent electrode films 4a and 4b of the first cell layer 1. Then, the light passes through the polarizer 8b when the OFF voltage is applied to the liquid crystal layer 6a. On the other hand, the light is shaded by the polarizer 8b when the ON voltage is applied thereto.

Namely, as shown in Fig. 6a, the red color light R, the green color light G and the blue color light B pass through each partial area of the polarizer 8b corresponding to each of a first group of pixels of the liquid crystal layer 6a to which the OFF voltage is applied, and then, a white color image is displayed on each of the first group of pixels. On the other hand, the red color light R, the green color light G and the blue color light B are shaded by each partial area of the polarizer 8b corresponding to each of a second group of pixels of the liquid crystal layer 6a to which the ON voltage is applied, and then, a black color image is displayed on each of the second group of pixels. Therefore, a monochromatic image composed of white and black color images is displayed on the double-layered-type liquid crystal device.

In the double-layered-type liquid crystal device, the second cell layer 2 acts as a compensator, resulting in an excellent monochromatic display without interference colors in the manner similar to that of the first preferred embodiment.

Next, a method for driving the double-layered-type liquid crystal device so as to display a multicolor image and the action thereof will be described below with reference to Fig. 6b.

Under the condition that a predetermined voltage is applied to the liquid crystal layer 6b of the second cell layer 2, the ON or OFF voltage is selectively applied to the liquid crystal layer 6a of the first cell layer 1 in the manner similar to the case of the aforementioned monochromatic display. Then, as shown in Fig. 6b, respective light transmittances of both the red color light R and the green color light G on each of a first group of pixels of the the liquid crystal layer 6a to which the OFF voltage is applied decrease, and then, a yellow color image is displayed on each of the first group of pixels. On the other hand, the red color light R, the green color light G and the blue color light B pass through each partial area of the polarizer 8b corresponding to each of a second group of pixels of the liquid crystal layer 6a to which the ON voltage is applied, and then, a white color image is displayed on each of the second group of pixels. Therefore, a two-color image composed of yellow and white color images is displayed on the double-layered-type liquid crystal device.

If the second cell layer 2 is driven statically so as to switch over from such a state that no voltage is applied to the substantially whole area of the liquid crystal 6b to such a state that a predetermined voltage is applied thereto, the whole image surface of the double-layered-type liquid crystal device can be switched over from a monochromatic display for selectively displaying a white color image or a black color image thereon to a two-color display for selectively displaying a yellow color image or a white color image thereon. Furthermore, by switching over from such a state that no voltage is applied to the whole area of the liquid crystal layer 6b of the second cell layer 2 corresponding to all the pixels to such a state that a predetermined voltage is applied only to a partial area of the liquid crystal layer 6b corresponding to any selected group of pixels with use of a simple multiplex driving method, a two-color image composed of yellow and white color images is displayed on the selected group of pixels under the condition that a monochromatic image composed of white and black color images is displayed on the other groups of pixels, resulting in a multicolor display on the whole surface of the double-layered-type liquid crystal device.

In the aforementioned present preferred embodiments, the double-layered-type liquid crystal device is described above; however the present invention is not limited to this construction. The present invention can be applied to a multi-layered-type liquid crystal device.

It is understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope of the present invention as defined by the appended claims.

Claims

1. A method of driving a multi-layered liquid crystal display device which comprises stacked plural cell layers (1,2), each cell layer containing a liquid crystal material (6a,6b) having molecules twisted between two transparent substrates (3a,3b;3b,3c) so as to exhibit a large birefringence, the device further comprising two polarizers (8a,8b) sandwiching said stacked plural cell layers, the method comprising applying a driving voltage to at least one (1) of

said cell layers, and being characterised by controlling a voltage at a further one (2) of said cell layers, so as to determine the color of the image displayed by the device solely by the interaction between the polarization filtering of the polarizers and the interference effects induced by the birefringence of the liquid crystal material (6a,6b) of the individual cell layers under the influence of said voltages.

2. The method as claimed in claim 1, wherein the voltage applied to at least one cell layer (2) is fixed, and the voltages applied to the other cell layers (1) are switched over between different predetermined voltages.

3. The method as claimed in any one of claims 1 and 2, wherein said liquid crystal display device is a double-layered liquid crystal display device composed of first and second cell layers (1,2).

4. The method as claimed in claim 3, wherein the relationship between the product of the birefringence Δn_1, the thickness d_1 and the twist angle θ_1 of said first cell layer (1) and the product of the birefringence Δn_2, the thickness d_2 and the twist angle θ_2 of said second cell layer (2) is set so as to satisfy the following inequality:

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 > 0.9,$$

said method comprising:
applying a predetermined voltage to said second cell layer (2); and
selectively applying a first predetermined voltage or a second predetermined voltage to said first cell layer (1), thereby displaying a monochromatic image on said liquid crystal display device.

5. The method as claimed in claim 3, wherein the relation between the product of the birefringence Δn_1, the thickness d_1 and the twist angle θ_1 of said first cell layer (1) and the product of the birefringence Δn_2, the thickness d_2 and the twist angle θ_2 of said second cell layer (2) is set so as to satisfy the following inequality:

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 > 0.9,$$

said method comprising:
applying no voltage to said second cell layer (2); and
selectively applying a first predetermined voltage or a second predetermined voltage to said first cell layer (1), thereby displaying a two-color image on said liquid crystal display device.

6. The method as claimed in claim 3, wherein the relation between the product of the birefringence Δn_1, the thickness d_1 and the twist angle θ_1 of said first cell layer (1) and the product of the birefringence Δn_2, the thickness d_2 and the twist angle θ_2 of said second cell layer (2) is set so as to satisfy the following inequality:

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 < 1.1,$$

said method comprising:
applying no voltage to said second cell layer (2); and
selectively applying a first predetermined voltage or a second predetermined voltage to said first cell layer (1), thereby displaying a monochromatic color image on said liquid crystal display device.

7. The method as claimed in claim 3, wherein the relation between the product of the birefringence Δn_1, the thickness d_1 and the twist angle θ_1 of said first cell layer (1) and the product of the birefringence Δn_2, the thickness d_2 and the twist angle θ_2 of said second cell layer (2) is set so as to satisfy the following inequality:

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 < 1.1,$$

said method comprising:
applying a predetermined voltage to said second cell layer (2); and
selectively applying a first predetermined voltage or a second predetermined voltage to said first cell layer, thereby displaying a two-color image on said liquid crystal display device.

8. The method as claimed in any one of the claims 3 to 7,

wherein the absolute value of the product of the birefringence Δn_1 and the thickness d_1 of said first cell layer

(1) is set so as to satisfy the following inequality:

$$1.0 < |\Delta n_1 \cdot d_1| < 3.5,$$

and the absolute value of the product of the birefringence Δn_2 and the thickness d_2 of said second cell layer (2) is set so as to satisfy the following inequality:

$$1.0 < |\Delta n_2 \cdot d_2| < 3.5.$$

9. The method as claimed in any one of the claims 3, 4 and 6,

wherein the ratio of the product of the birefringence Δn_2 and the thickness d_2 of said second cell layer (2) to the product of the birefringence Δn_1 and the thickness d_1 of said first cell layer (1) is set so as to satisfy the following inequality:

$$0.8 < (\Delta n_2 \cdot d_2)/(\Delta n_1 \cdot d_1) < 1.5.$$

10. The method as claimed in any one of the claims 3, 4 and 6,

wherein the twist angle of said first cell layer (1) is set so as to fall in the range from 180° to 360° and the twist angle of said second cell layer (2) is set so as to fall in the range from 30° to 360° and to be different from that of said first cell layer (1).

11. The method as claimed in any one of the claims 3 to 7,

wherein the ratio of the thickness d of each of said first (1) and second (2) cell layers to the helical pitch p of the liquid crystal therein is set so as to satisfy the following inequality under the condition that the pretilt angle of the liquid crystal thereof is equal to or smaller than 10°:

$$\Theta/360° - 1/4 < d/p \leq \Theta/360°,$$

wherein Θ is the twist angle of the liquid crystal in each of said first and second cell layers (1,2).

12. The method of any of claims 4 to 11, further comprising the step of switching over between

a state in which a predetermined voltage is applied to said second cell layer (2) and a first predetermined voltage or a second predetermined voltage is selectively applied to said first cell layer (1), and
a state in which a zero voltage is applied to said second cell layer (2) and a first predetermined voltage or a second predetermined voltage is selectively applied to said first cell layer (1).

13. A liquid crystal display device comprising:

a plurality of stacked liquid crystal cell layers (1,2), each cell layer containing a liquid crystal material (6a,6b) twisted between two transparent substrates (3a,3b;3b,3c) so as to exhibit a large birefringence which varies according to the voltage applied to the respective cell layer, the device further comprising
two polarizers (8a,8b) arranged to sandwich said plurality of stacked liquid crystal layers, and
first electrode means (4a,4b) for applying a driving voltage to a first one (1) of said cell layers,
characterised by
second electrode means (4c,4d) for controlling a voltage applied to a second one (2) of said cell layers, and by the color of the image displayed by the device being determined solely by the interaction between the polarization filtering of the polarizers and the interference effects induced by the birefringence of the liquid crystal material (6a,6b) of the individual cell layers under the influence of said voltages.

Patentansprüche

1. Verfahren zum Ansteuern einer mehrschichtigen Flüssigkristall-Anzeigevorrichtung mit mehreren aufeinandergeschichteten Zellenschichten (1, 2), von denen jede ein Flüssigkristallmaterial (6a, 6b) mit zwischen zwei transparenten Substraten (3a, 3b; 3b, 3c) verdrillten Molekülen enthält, um große Doppelbrechung aufzuweisen, wobei die Vorrichtung ferner zwei die mehreren aufeinandergeschichteten Zellenschichten einbettenden Polarisatoren (8a, 8b) aufweist, wobei gemäß dem Verfahren eine Ansteuerspannung an mindestens eine (1) der Zellenschichten

angelegt wird, **gekennzeichnet durch** ein Einstellen einer Spannung an einer weiteren (2) der Zellenschichten, um die Farbe des durch die Vorrichtung angezeigten Bilds ausschließlich durch die Wechselwirkung zwischen der Polarisationsfilterung durch die Polarisatoren und den Interferenzeffekten zu bestimmen, wie sie durch die Doppelbrechung des Flüssigkristallmaterials (6a, 6b) der einzelnen Zellenschichten unter dem Einfluß der Spannungen hervorgerufen werden.

2. Verfahren nach Anspruch 1, bei dem die an mindestens eine Zellenschicht (2) angelegte Spannung festgehalten wird und die an die anderen Zellenschichten (1) angelegten Spannungen zwischen verschiedenen vorgegebenen Spannungen umgeschaltet werden.

3. Verfahren nach einem der Ansprüche 1 oder 2, bei dem die Flüssigkristall-Anzeigevorrichtung eine zweischichtige Flüssigkristall-Anzeigevorrichtung ist, die aus einer ersten und einer zweiten Zellenschicht (1, 2) besteht.

4. Verfahren nach Anspruch 3, bei dem die Beziehung zwischen dem Produkt aus der Doppelbrechung Δn_1, der Dicke d_1 und dem Verdrillungswinkel Θ_1 für die erste Zellenschicht (1) und dem Produkt aus der Doppelbrechung Δn_2, der Dicke d_2 und dem Verdrillungswinkel Θ_2 für die zweite Zellenschicht (2) so eingestellt ist, daß sie der folgenden Ungleichung genügt:

$$\Delta n_2 \cdot d_2 \, . \, \Theta_2 \, / \, \Delta n_1 \cdot d_1 \cdot \Theta_1 > 0{,}9,$$

wobei das Verfahren folgendes umfaßt:

- Anlegen einer vorgegebenen Spannung an die zweite Zellenschicht (2) und
- selektives Anlegen einer ersten vorgegebenen Spannung oder einer zweiten vorgegebenen Spannung an die erste Zellenschicht (1), um dadurch ein monochromes Bild auf der Flüssigkristall-Anzeigevorrichtung anzuzeigen.

5. Verfahren nach Anspruch 3, bei dem die Beziehung zwischen dem Produkt aus der Doppelbrechung Δn_1, der Dicke d_1 und dem Verdrillungswinkel Θ_1 für die erste Zellenschicht (1) und dem Produkt aus der Doppelbrechung Δn_2, der Dicke d_2 und dem Verdrillungswinkel Θ_2 für die zweite Zellenschicht (2) so eingestellt ist, daß sie der folgenden Ungleichung genügt:

$$\Delta n_2 \, . \, d_2 \, . \, \Theta_2 \, / \, \Delta n_1 \, . \, d_1 \, . \, \Theta_1 > 0{,}9,$$

wobei das Verfahren folgendes umfaßt:

- Anlegen keiner Spannung an die zweite Zellenschicht (2) und
- selektives Anlegen einer ersten vorgegebenen Spannung oder einer zweiten vorgegebenen Spannung an die erste Zellenschicht (1), um dadurch ein zweifarbiges Bild auf der Flüssigkristall-Anzeigevorrichtung anzuzeigen.

6. Verfahren nach Anspruch 3, bei dem die Beziehung zwischen dem Produkt aus der Doppelbrechung Δn_1, der Dicke d_1 und dem Verdrillungswinkel Θ_1 für die erste Zellenschicht (1) und dem Produkt aus der Doppelbrechung Δn_2, der Dicke d_2 und dem Verdrillungswinkel Θ_2 für die zweite Zellenschicht (2) so eingestellt ist, daß sie der folgenden Ungleichung genügt:

$$\Delta n_2 \cdot d_2 \cdot \Theta_2 \, / \, \Delta n_1 \cdot d_1 \cdot \Theta_1 < 1{,}1,$$

wobei das Verfahren folgendes umfaßt:

- Anlegen keiner Spannung an die zweite Zellenschicht (2) und
- selektives Anlegen einer ersten vorgegebenen Spannung oder einer zweiten vorgegebenen Spannung an die erste Zellenschicht (1), um dadurch ein monochromes Bild auf der Flüssigkristall-Anzeigevorrichtung anzuzeigen.

7. Verfahren nach Anspruch 3, bei dem die Beziehung zwischen dem Produkt aus der Doppelbrechung Δn_1, der Dicke d_1 und dem Verdrillungswinkel Θ_1 für die erste Zellenschicht (1) und dem Produkt aus der Doppelbrechung Δn_2, der Dicke d_2 und dem Verdrillungswinkel Θ_2 für die zweite Zellenschicht (2) so eingestellt ist, daß sie der folgenden Ungleichung genügt:

$$\Delta n_2 \cdot d_2 \cdot \Theta_2 \, / \, \Delta n_1 \cdot d_1 \cdot \Theta_1 < 1{,}1,$$

wobei das Verfahren folgendes umfaßt:

- Anlegen einer vorgegebenen Spannung an die zweite Zellenschicht (2) und
- selektives Anlegen einer ersten vorgegebenen Spannung oder einer zweiten vorgegebenen Spannung an die erste Zellenschicht, zum Anzeigen eines zweifarbigen Bilds auf der Flüssigkristall-Anzeigevorrichtung.

8. Verfahren nach einem der Ansprüche 3 bis 7, bei dem

- der Absolutwert des Produkts aus der Doppelbrechung Δn_1 und der Dicke d_1 der ersten Zellenschicht (1) so eingestellt ist, daß die folgende Ungleichung erfüllt ist:

$$1{,}0 < | \Delta n_1 \cdot d_1 | < 3{,}5; \text{ und}$$

- der Absolutwert des Produkts aus der Doppelbrechung Δn_2 und der Dicke d_2 der zweiten Zellenschicht (2) so eingestellt ist, daß die folgende Ungleichung erfüllt ist:

$$1{,}0 < | \Delta n_2 \cdot d_2 | < 3{,}5.$$

9. Verfahren nach einem der Ansprüche 3, 4 oder 6, bei dem das Verhältnis aus dem Produkt der Doppelbrechung Δn_2 und der Dicke d_2 der zweiten Zellenschicht (2) zum Produkt aus der Doppelbrechung Δn_1 und der Dicke d_1 der ersten Zellenschicht (1) so eingestellt ist, daß die folgende Ungleichung erfüllt ist:

$$0{,}8 < (\Delta n_2 \cdot d_2) / (\Delta n_1 \cdot d_1) < 1{,}5.$$

10. Verfahren nach einem der Ansprüche 3, 4 oder 6, bei dem

- der Verdrillungswinkel der ersten Zellenschicht (1) so eingestellt wird, daß er in den Bereich von 180° bis 360° fällt; und
- der Verdrillungswinkel der zweiten Zellenschicht (2) so eingestellt ist, daß er in den Bereich von 30° bis 360° fällt und sich von dem der ersten Zellenschicht (1) unterscheidet.

11. Verfahren nach einem der Ansprüche 3 bis 7, bei dem das Verhältnis aus der Dicke d der ersten (1) und der zweiten (2) Zellenschicht zur Schraubenganghöhe p des darin enthaltenen Flüssigkristalls so eingestellt ist, daß die folgende Ungleichung erfüllt ist, wenn der Vorneigungswinkel des dort vorhandenen Flüssigkristalls 10° entspricht oder kleiner ist:

$$\Theta / 360° - 1/4 < d/p \leq \Theta / 360°,$$

wobei Θ der Verdrillungswinkel des Flüssigkristalls sowohl in der ersten als auch der zweiten Zellenschicht (1, 2) ist.

12. Verfahren nach einem der Ansprüche 4 bis 11, ferner mit dem Schritt des Umschaltens zwischen

- einem Zustand, in dem eine vorgegebene Spannung an die zweite Zellenschicht (2) angelegt wird und eine erste vorgegebene Spannung oder eine zweite vorgegebene Spannung selektiv an die erste Zellenschicht (1) angelegt wird; und
- einem Zustand, in dem die Spannung null an die zweite Zellenschicht (2) angelegt wird und eine erste vorgegebene Spannung oder eine zweite vorgegebene Spannung selektiv an die erste Zellenschicht (1) angelegt wird.

13. Flüssigkristall-Anzeigevorrichtung mit:

- mehreren aufeinandergeschichteten Flüssigkristallzelle-Schichten (1, 2), von denen jede ein Flüssigkristallmaterial (6a, 6b) enthält, das zwischen zwei transparenten Substraten (3a, 3b; 3b, 3c) verdrillt ist, um große Doppelbrechung zu aufzuweisen, die abhängig von der an die jeweilige Zellenschicht angelegten Spannung variiert, wobei die Vorrichtung ferner folgendes aufweist:
- zwei Polarisatoren (8a, 8b), die so angeordnet sind, daß sie die mehreren aufeinandergeschichteten Flüssigkristallschichten einbetten; und
- eine erste Elektrodeneinrichtung (4a, 4b) zum Anlegen einer Ansteuerspannung an eine erste (1) der Zellenschichten; **gekennzeichnet durch**
- eine zweite Elektrodeneinrichtung (4c, 4d) zum Einstellen einer an eine zweite (2) der Zellenschichten angelegten Spannung;
- wobei die Farbe des durch die Vorrichtung angezeigten Bilds ausschließlich durch die Wechselwirkung zwischen der Polarisationsfilterung durch die Polarisatoren und den Interferenzeffekten bestimmt wird, wie sie

durch die Doppelbrechung des Flüssigkristallmaterials (6a, 6b) der einzelnen Zellenschichten unter dem Einfluß der Spannungen hervorgerufen werden.

Revendications

1. Procédé de pilotage d'un dispositif d'affichage à cristaux liquides du type multicouches qui comprend des couches de cellules multiples empilées (1, 2), chaque couche de cellules contenant une matière formant cristal liquide (6a, 6b) ayant des molécules en hélice entre deux substrats transparents (3a, 3b ; 3b, 3c) de façon à montrer une grande biréfringence, le dispositif comprenant, de plus, deux polariseurs (8a, 8b) prenant en sandwich lesdites couches de cellules multiples empilées, le procédé comprenant l'application d'une tension de pilotage à au moins une (1) desdites couches de cellules, et étant caractérisé par la commande d'une tension au niveau d'une couche supplémentaire (2) desdites couches de cellules, de façon à déterminer la couleur de l'image affichée par le dispositif seul par l'interaction entre le filtrage par polarisation des polariseurs et les effets d'interférence induits par la biréfringence de la matière formant cristal liquide (6a, 6b) des couches de cellules individuelles sous l'influence desdites tensions.

2. Procédé selon la revendication 1, dans lequel la tension appliquée à au moins une couche de cellules (2) est fixe, et les tensions appliquées aux autres couches de cellules (1) sont commutées parmi différentes tensions prédéterminées.

3. Procédé selon l'une quelconque des revendications 1 et 2, dans lequel ledit dispositif d'affichage à cristaux liquides est un dispositif d'affichage à cristaux liquides du type à double couche composé de première et de seconde couches de cellules (1, 2).

4. Procédé selon la revendication 3, dans lequel la relation entre le produit de la biréfringence Δn_1, l'épaisseur d_1 et l'angle d'hélice θ_1 de ladite première couche de cellules (1) et le produit de la biréfringence Δn_2, l'épaisseur d_2 et l'angle d'hélice θ_2 de ladite seconde couche de cellules (2) est fixée de façon à satisfaire l'inégalité suivante :

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 > 0{,}9$$

ledit procédé comprenant :

l'application d'une tension prédéterminée à ladite seconde couche de cellules (2) ; et
l'application, de manière sélective, d'une première tension prédéterminée ou d'une seconde tension prédéterminée à ladite première couche de cellules (1), affichant, de ce fait, une image monochromatique sur ledit dispositif d'affichage à cristaux liquides.

5. Procédé selon la revendication 3, dans lequel la relation entre le produit de la biréfringence Δn_1, l'épaisseur d_1 et l'angle d'hélice θ_1 de ladite première couche de cellules (1) et le produit de la biréfringence Δn_2, l'épaisseur d_2 et l'angle d'hélice θ_2 de ladite seconde couche de cellules (2) est fixée de façon à satisfaire l'inégalité suivante :

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 > 0{,}9$$

ledit procédé comprenant :

la non-application d'une tension à ladite seconde couche de cellules (2) ; et
l'application, de manière sélective, d'une première tension prédéterminée ou d'une seconde tension prédéterminée à ladite première couche de cellules (1), affichant, de ce fait, une image en deux couleurs sur ledit dispositif d'affichage à cristaux liquides.

6. Procédé selon la revendication 3, dans lequel la relation entre le produit de la biréfringence Δn_1, l'épaisseur d_1 et l'angle d'hélice θ_1 de ladite première couche de cellules (1) et le produit de la biréfringence Δn_2, l'épaisseur d_2 et l'angle d'hélice θ_2 de ladite seconde couche de cellules (2) est fixée de façon à satisfaire l'inégalité suivante :

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 < 1{,}1$$

ledit procédé comprenant :

la non-application d'une tension à ladite seconde couche de cellules (2) ; et
l'application, de manière sélective, d'une première tension prédéterminée ou d'une seconde tension prédéterminée à ladite première couche de cellules (1), affichant, de ce fait, une image couleur monochromatique sur

ledit dispositif d'affichage à cristaux liquides.

7. Procédé selon la revendication 3, dans lequel la relation entre le produit de la biréfringence Δn_1, l'épaisseur d_1 et l'angle d'hélice θ_1 de ladite première couche de cellules (1) et le produit de la biréfringence Δn_2, l'épaisseur d_2 et l'angle d'hélice θ_2 de ladite seconde couche de cellules (2) est fixée de façon à satisfaire l'inégalité suivante :

$$\Delta n_2 \cdot d_2 \cdot \theta_2 / \Delta n_1 \cdot d_1 \cdot \theta_1 < 1{,}1$$

ledit procédé comprenant :

l'application d'une tension prédéterminée à ladite seconde couche de cellules (2) ; et
l'application, de manière sélective, d'une première tension prédéterminée ou d'une seconde tension prédéterminée à ladite première couche de cellules, affichant, de ce fait, une image en deux couleurs sur ledit dispositif d'affichage à cristaux liquides.

8. Procédé selon l'une quelconque des revendications 3 à 7,

dans lequel la valeur absolue du produit de la biréfringence Δn_1 et de l'épaisseur d_1 de ladite première couche de cellules (1) est fixée de façon à satisfaire l'inégalité suivante :

$$1{,}0 < |\Delta n_1 \cdot d_1| < 3{,}5$$

et la valeur absolue du produit de la biréfringence Δn_2 et de l'épaisseur d_2 de ladite seconde couche de cellules (2) est fixée de façon à satisfaire l'inégalité suivante :

$$1{,}0 < |\Delta n_2 \cdot d_2| < 3{,}5.$$

9. Procédé selon l'une quelconque des revendications 3, 4 et 6,

dans lequel le rapport du produit de la biréfringence Δn_2 et de l'épaisseur d_2 de ladite seconde couche de cellules (2) sur le produit de la biréfringence Δn_1 et de l'épaisseur d_1 de ladite première couche de cellules (1) est fixée de façon à satisfaire l'inégalité suivante :

$$0{,}8 < (\Delta n_2 \cdot d_2) / (\Delta n_1 \cdot d_1) < 1{,}5.$$

10. Procédé selon l'une quelconque des revendications 3, 4 et 6,

dans lequel l'angle d'hélice de ladite première couche de cellules (1) est fixé de façon à tomber dans la plage de 180° à 360° et
l'angle d'hélice de ladite seconde couche de cellules (2) est fixé de façon à tomber dans la plage de 30° à 360° et de façon à être différent de celui de ladite première couche de cellules (1).

11. Procédé selon l'une quelconque des revendications 3 à 7,

dans lequel le rapport de l'épaisseur d de chacune desdites première (1) et seconde (2) couches de cellules sur le pas d'hélice p du cristal liquide dans ces dernières est fixé de façon à satisfaire l'inégalité suivante à condition que l'angle de préinclinaison du cristal liquide de ces dernières soit égal ou inférieur à 10° :

$$\theta/360° - 1/4 < d/p \leq \theta/360°,$$

dans laquelle θ est l'angle d'hélice du cristal liquide dans chacune desdites première et seconde couches de cellules (1, 2).

12. Procédé selon l'une quelconque des revendications 4 à 11 comprenant, de plus, l'étape de commutation entre :

un état dans lequel une tension prédéterminée est appliquée à ladite seconde couche de cellules (2) et dans lequel une première tension prédéterminée ou une seconde tension prédéterminée est appliquée, de manière sélective, à ladite première couche de cellules (1), et
un état dans lequel une tension nulle est appliquée à ladite seconde couche de cellules (2) et dans lequel une première tension prédéterminée ou une seconde tension prédéterminée est appliquée, de manière sélective, à ladite première couche de cellules (1).

13. Dispositif d'affichage à cristaux liquides comprenant :

plusieurs couches de cellules à cristaux liquides empilées (1, 2), chaque couche de cellules contenant une matière formant cristal liquide (6a, 6b) mise en hélice entre deux substrats transparents (3a, 3b ; 3b, 3c) de façon à montrer une grande biréfringence qui varie selon la tension appliquée à la couche de cellules respective, le dispositif comprenant, de plus :
deux polariseurs (8a, 8b) conçus pour prendre en sandwich lesdites plusieurs couches de cristaux liquides empilées, et
un premier moyen formant électrode (4a, 4b) pour appliquer une tension de pilotage à une première couche particulière (1) desdites couches de cellules,
caractérisé par
un second moyen formant électrode (4c, 4d) pour commander une tension appliquée à une seconde couche particulière (2) desdites couches de cellules, et par
la couleur de l'image affichée par le dispositif étant déterminée seulement par l'interaction entre le filtrage par polarisation des polariseurs et les effets d'interférence induits par la biréfringence de la matière formant cristal liquide (6a, 6b) des couches de cellules individuelles sous l'influence desdites tensions.

Fig . 1

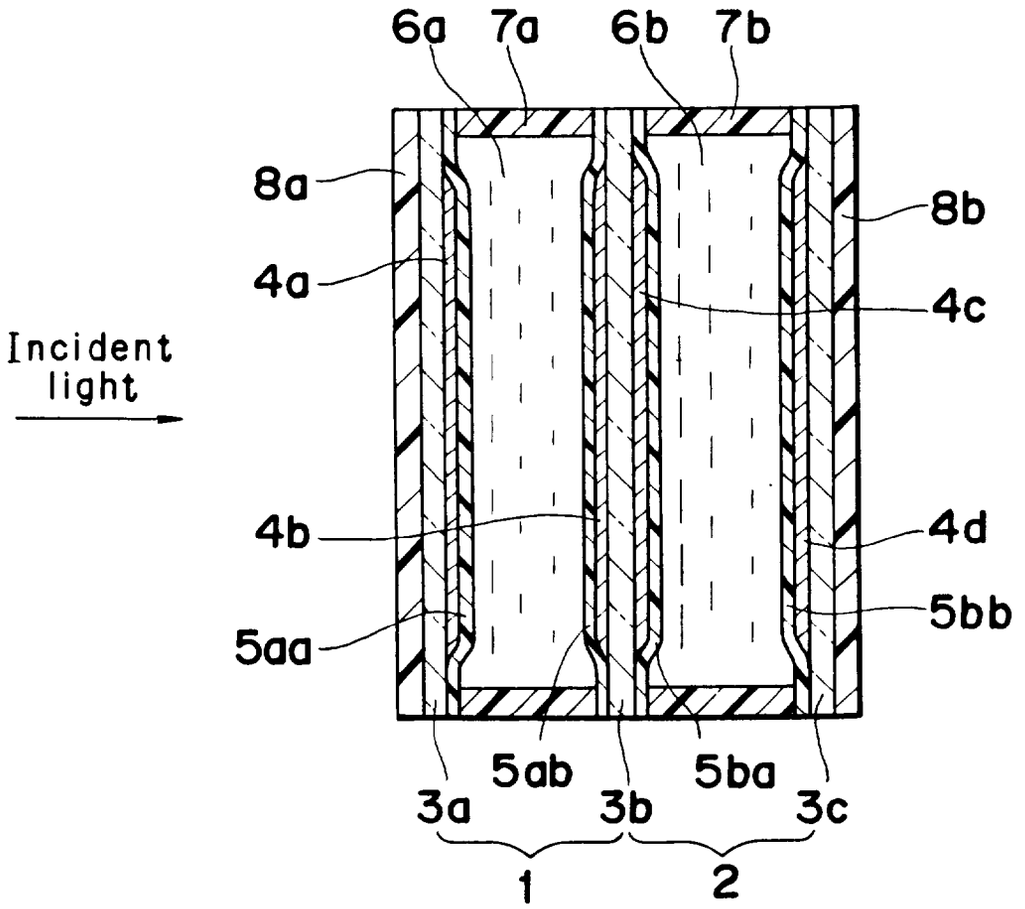


Fig . 2a

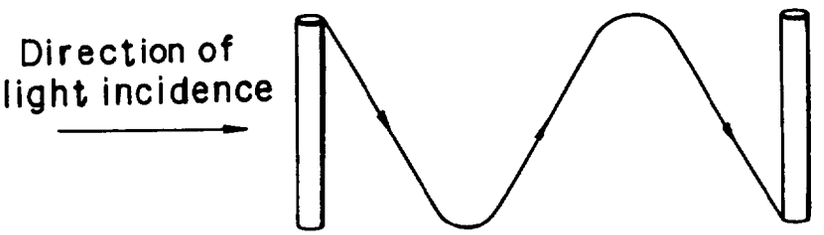


Fig . 2b

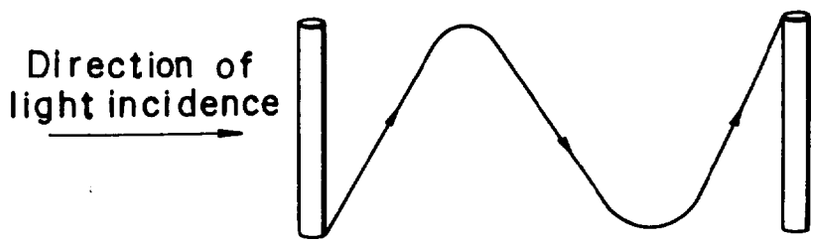


Fig. 3

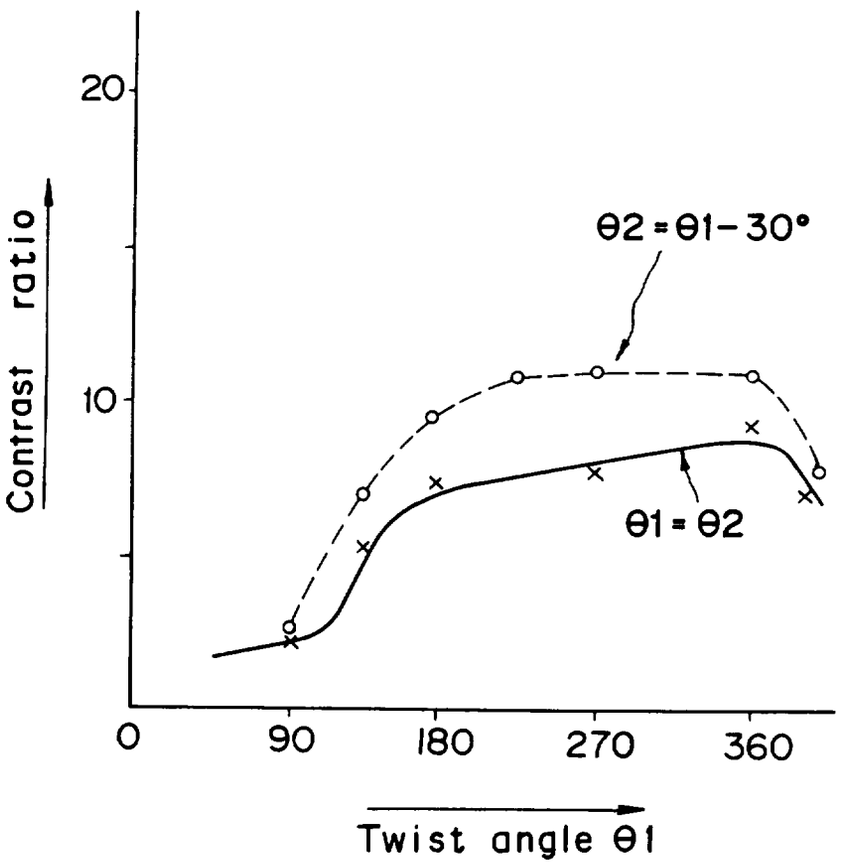

20
10
Contrast ratio
θ2 = θ1 − 30°
θ1 = θ2
0
90
180
270
360
Twist angle θ1

Fig. 4a

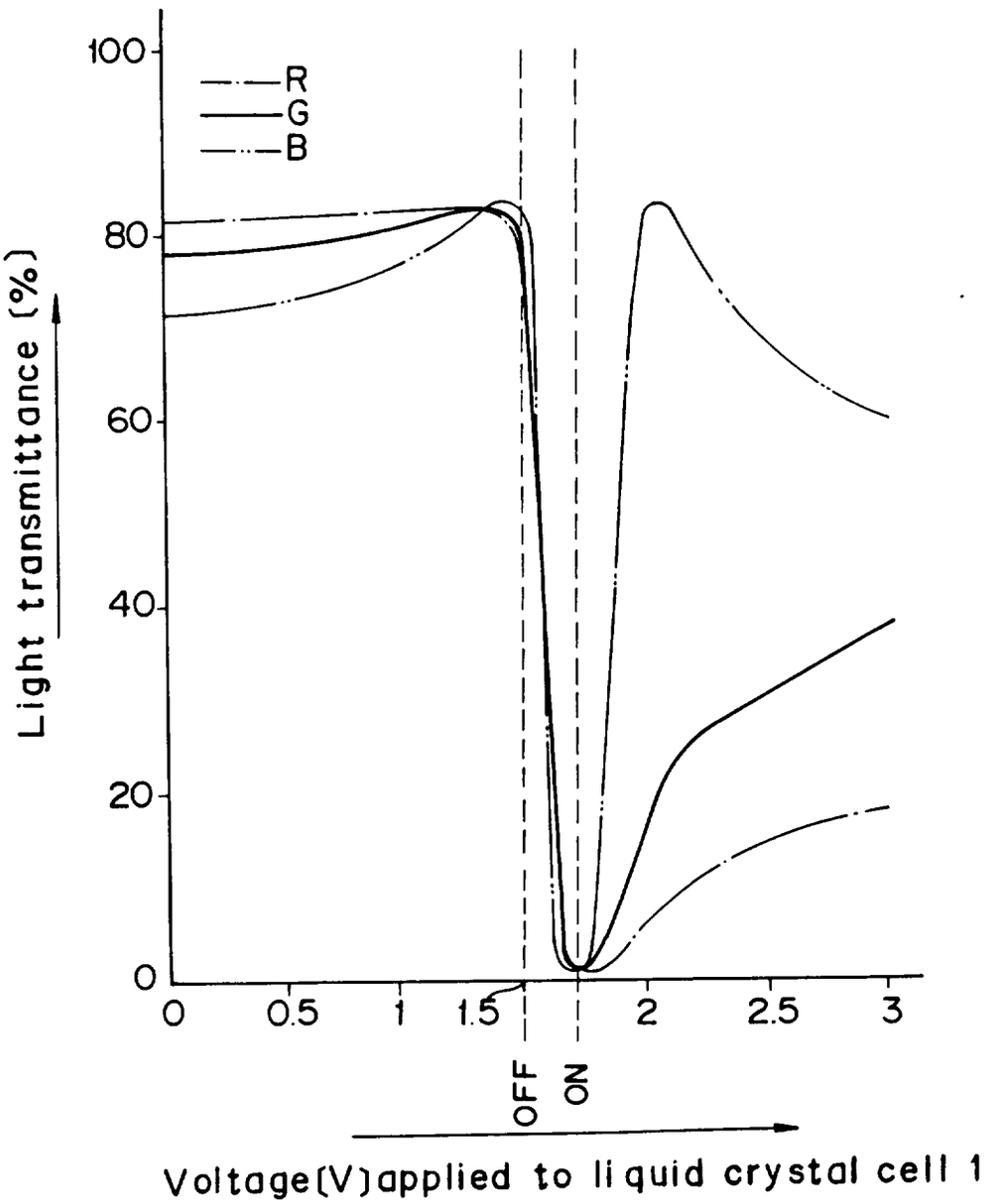

100
80
60
40
20
0
R
G
B
Light transmittance (%)
0
0.5
1
1.5
2
2.5
3
OFF
ON
Voltage(V)applied to liquid crystal cell 1

Fig . 4b

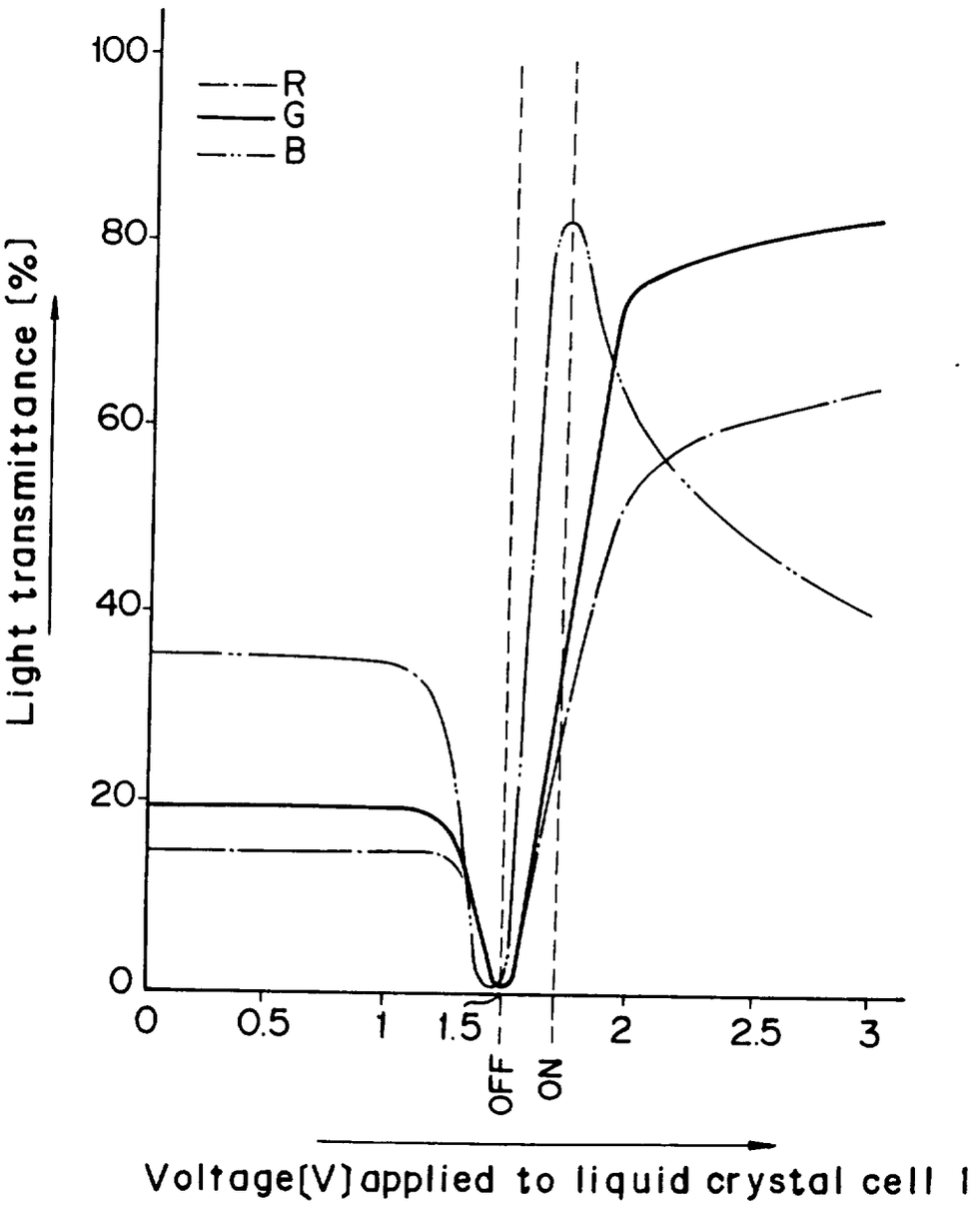

100
80
60
40
20
0
R
G
B
Light transmittance [%]
0
0.5
1
1.5
2
2.5
3
OFF
ON
Voltage[V] applied to liquid crystal cell 1

Fig. 5a

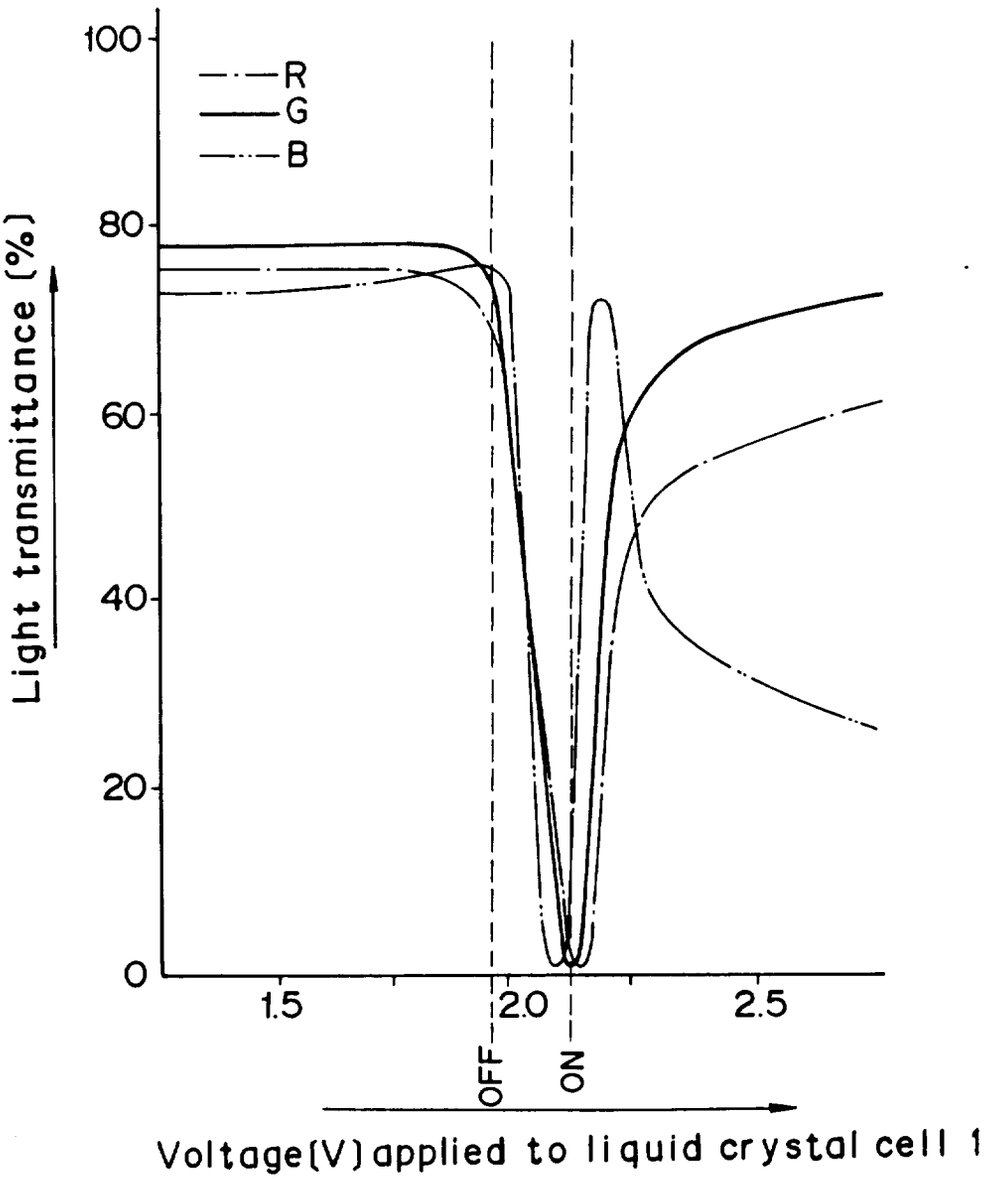

100
80
60
40
20
0
R
G
B
Light transmittance (%)
1.5
2.0
2.5
OFF
ON
Voltage(V) applied to liquid crystal cell 1

Fig. 5b

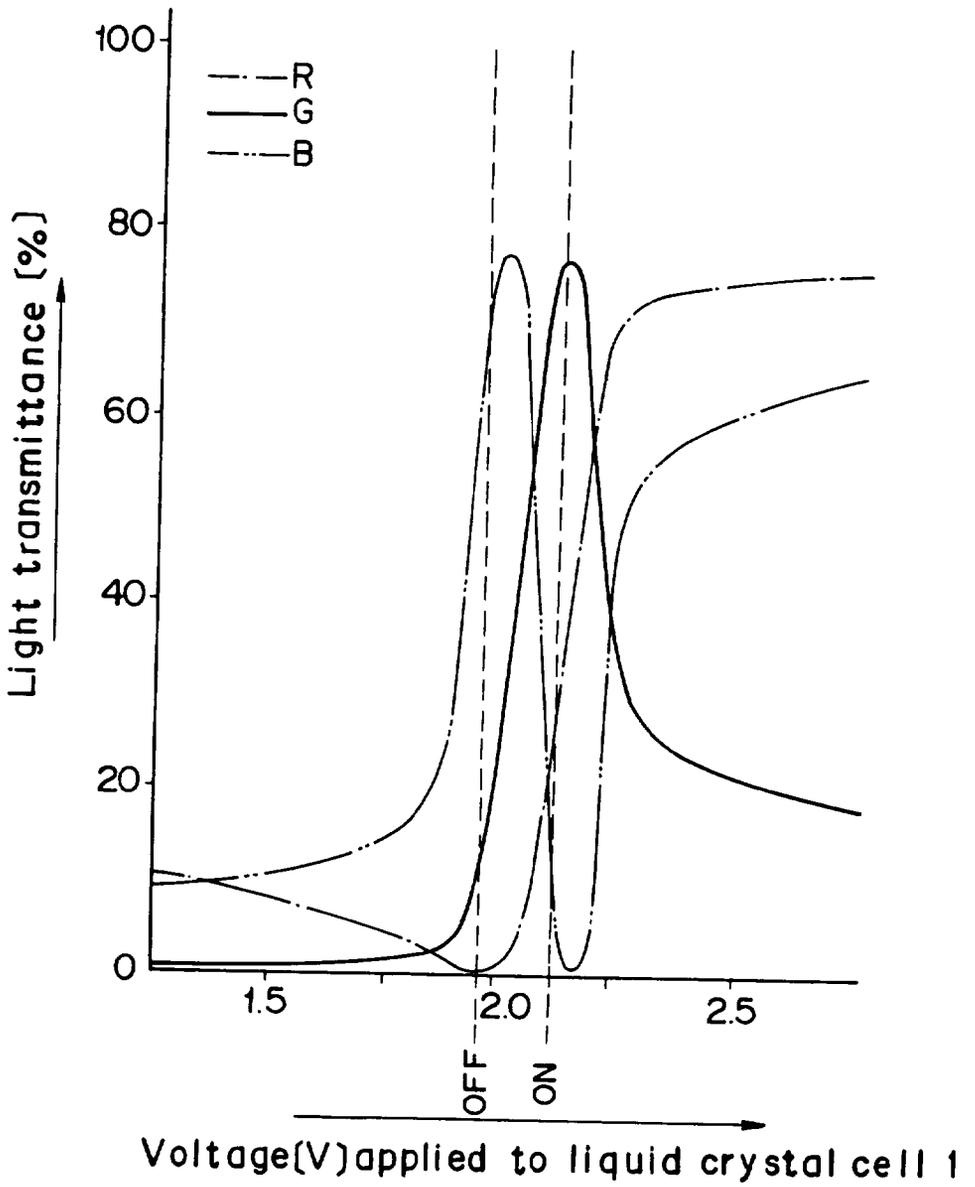

100
80
60
40
20
0
R
G
B
Light transmittance [%]
1.5
2.0
2.5
OFF
ON
Voltage(V)applied to liquid crystal cell 1

Fig. 6a

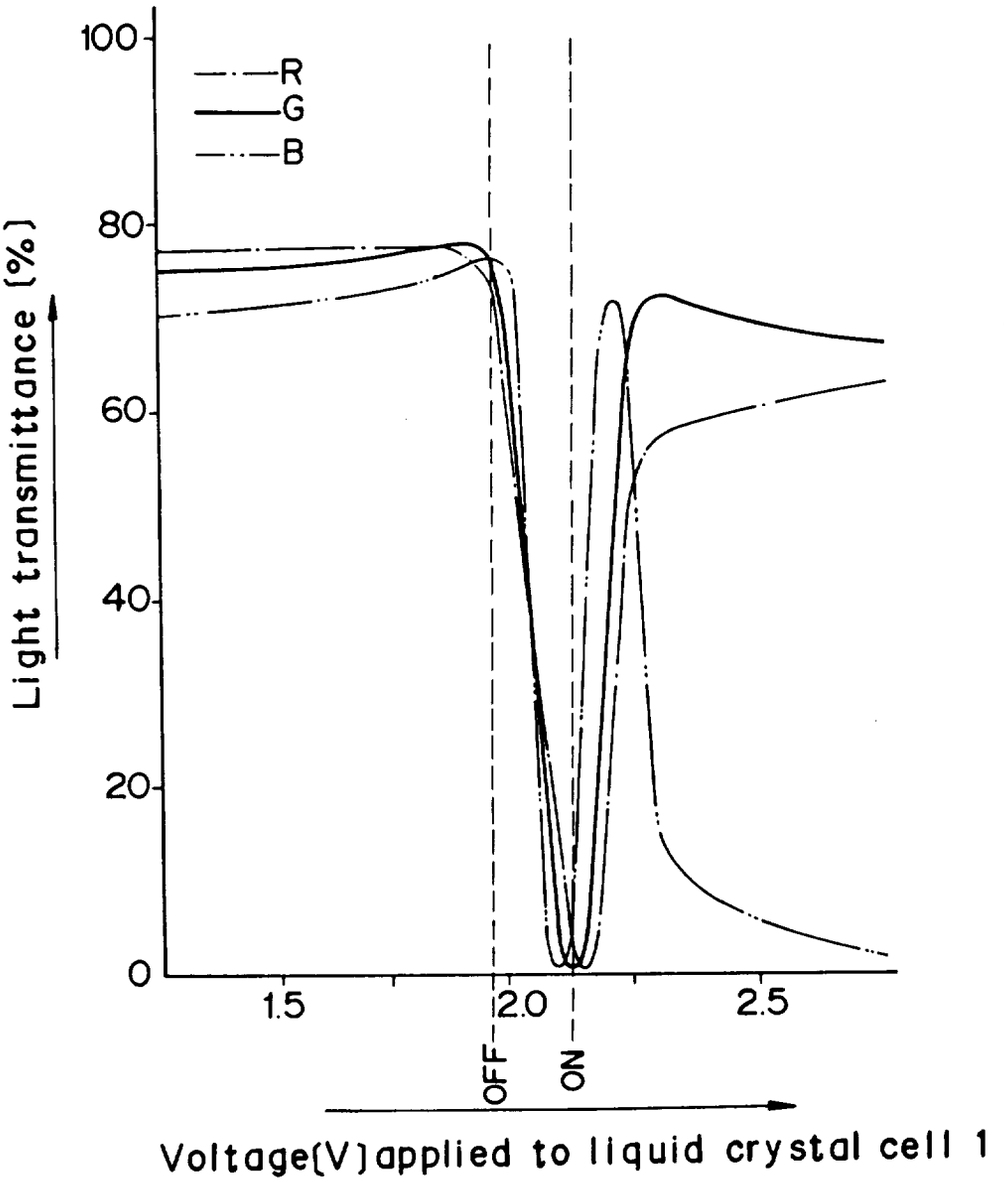
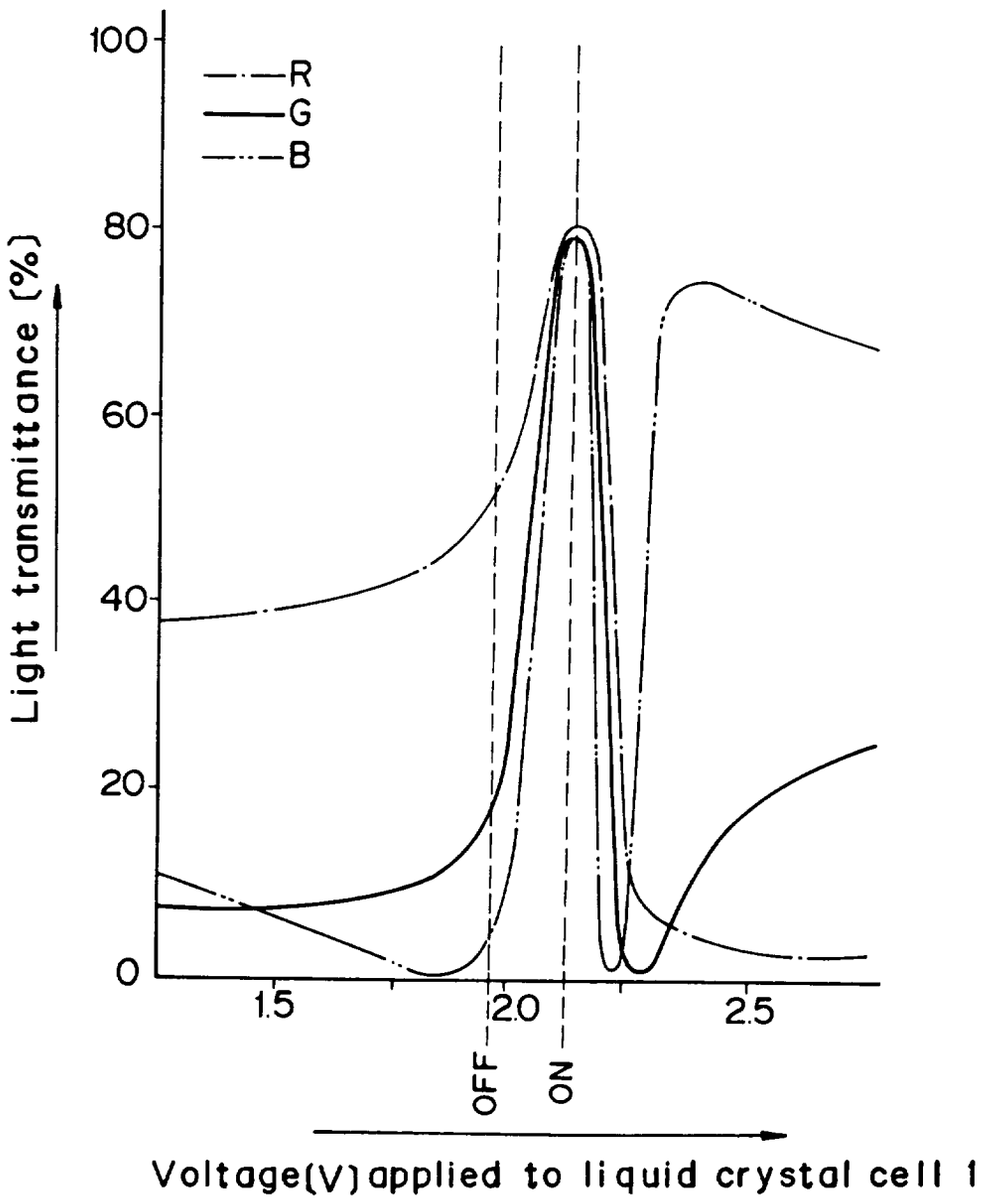

100
80
60
40
20
0
R
G
B
Light transmittance (%)
1.5
2.0
2.5
OFF
ON
Voltage(V) applied to liquid crystal cell 1

Fig. 6b


100
80
60
40
20
0
R
G
B
Light transmittance (%)
1.5
2.0
2.5
OFF
ON
Voltage(V) applied to liquid crystal cell 1